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(54) ELECTRIC DRIVE UNIT FOR HIGH-SPEED APPLIANCES FOR EXAMPLE GAS ULTRA-CENTRIFUGES

(71) We, DORNIER AG., a German company, of 799 Friedrichshafen/Bodensee, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electric drive unit for a high-speed appliance, for example a gas ultracentrifuge for isolating a gas mixture, particularly an isotope mixture. A high-speed gas ultracentrifuge is usually constructed so that its rotor or its centrifuge drum rotates in a vacuum chamber. Shaft drive is therefore virtually unusable, so that such a centrifuge is operated by a drive unit which has no direct mechanical contact with the rotor or drum. A drive unit is known having a rotary field and a stator carrying windings, the stator being disposed in the housing of the centrifuge. With this arrangement, a rotor in the form of a core or ring or a disc is disposed on the centrifuge rotor. The rotor can be disposed inside or outside the stator. This rotor is set in motion by the rotary field and rotates, after starting, synchronously with the rotary field, e.g. in the case of a hysteresis motor. Various constructions of these centrifuge rotors and rotor means are known. In one known embodiment (German Patent Specification No. 1,071,593), the rotor forms a part of the bottom plate of the centrifuge drum and the windings of the stator for generating the rotary field are disposed on the bottom of the housing, underneath this bottom plate.

According to another known embodiment (German Patent Specification No. 1,220,341), the stator windings for the rotary field are disposed on the side wall of the housing. In this case, the rotor is constructed as a sleeve which protrudes from the bottom of the centrifuge rotor in between the windings.

It is conventional for the drive unit to be supplied with three-phase alternating

current. The working frequency for the unit can be provided from the electricity supply mains by special medium-frequency generators or also by rotating or static transverters. However, separate medium frequency generators of for example 1100 Hz necessitate considerable expenditure. Also, difficulties reside in that such a centrifuge cannot operate without vibration and therefore requires, its own separate and heavy mounting. Otherwise, operation of the centrifuge might suffer. Also such a machine requires servicing frequently and is subject to considerable wear and tear. In the case of large-scale centrifuge installations (e.g. cascades), the power transfer from the machines to the drive units results in relatively high losses in the installation. In addition, powerful generators or machine inverters are necessary. Static transverters, e.g. thyristor transverters, can be built in relatively small units and set up in the immediate vicinity of the consumer units, so that power losses within the installation as a whole are reduced. This does constitute an economic advantage over machine transverters or generators. In addition, these components also operate free of vibration, so that the problems of mounting do not occur. On the other hand, according to their design, so their voltage may be six or twelve-phase and this requires that the current should have a harmonics content which is disadvantageous, particularly in the case of a hysteresis motor such is as conventionally used in centrifuges. This harmonics content results in an additional heating of the rotor disc. Uncontrolled rotor disc heating can however have a disadvantageous effect on the physical process of separation within the centrifuge.

It is an object of the invention to provide for a gas ultracentrifuge a drive unit which does not have, or largely avoids, the above-mentioned disadvantages and which therefore when used in a large installation would result in transfer of power to the unit

with substantially reduced losses and which moreover has a small content of harmonics in the drive current. Constancy of frequency, combined with a high degree of efficiency, should also be provided.

According to the invention, there is provided an electric drive unit for a high-speed appliance, the unit having a rotary electrical field acting on a rotor part (for example a hysteresis rotor) wherein each phase of a drive winding, by incorporation of a capacitance, is constructed as a series oscillatory circuit tuned to an operating frequency, and wherein a remotely-actuated control unit alternately applies a direct current voltage to the oscillatory circuit or short-circuits the oscillatory circuit at a switch-over frequency corresponding to the operating frequency. The control unit preferably has electronic switches, for example transistors or thyristors.

As mentioned above, in a large-scale installation, power distribution at medium frequency has considerable drawbacks. By use of the invention, power is now transferred by means of direct current. This obviates the losses of medium frequency transmission, i.e. only ohmic losses occur in the supply conductor and only effective power is transferred. The amount of power required for control purposes is small. It is possible to operate a group of drive units in association with one another. In this case the individual phases are connected *inter se*. Similarly, series connection, parallel connection and combined series/parallel connection of a group of drive units is possible. The invention is not only economical by virtue of its above-mentioned advantages but also by virtue of its low manufacturing costs, and offers reliability by reason of its simple construction. Even in the associated operation principle, the proposed drive unit presents no problems of "hunting". The drive unit is suitable for higher frequencies, since in this case small size capacitors can be employed. The hysteresis motor is particularly suitable for the drive unit, since with this method of connection the less the damping of the oscillatory circuit, the poorer is the $\cos \phi$ rating of the motor.

The invention will now be described by way of example, with reference to the attached diagrammatic drawings, in which:—

Figure 1 is a diagram of a single-phase arrangement, to illustrate the principle of the invention;

Figure 2 shows a modified form of Figure 1, but using electronic switches;

Figure 3 shows a three-phase embodiment of the invention;

Figure 4 corresponds to the embodiment

of Figure 3, but using electronic switches;

Figure 5 shows the parallel connection of a plurality of drive units to form one group;

Figure 6 shows a modified form of Figure 5 with a single control device for all the drive units in the group;

Figure 7 shows a combined series/parallel connection of drive units.

Figure 1 shows one phase of a motor winding, with an inductance L and an effective resistance W , according to the operating frequency. On the input side of both these members there is in addition a capacitor C . The capacitance is such that the three members C , L and W form a series oscillatory circuit for the desired operating frequency of the drive unit. On the input side of this series oscillating circuit is a control unit E which includes two switches $S1$ and $S2$. The entire circuit is fed by the direct current U . The switches $S1$ and $S2$ are so constructed that in each case one switch is open when the other is closed or *vice versa*. The switch may in itself be constructed in any desired manner and offers no problem to a man skilled in the art. For the sake of clarity, mechanical contacts have been shown.

In order to operate the drive unit, the switches $S1$ and $S2$ in the control unit E are actuated at such a switch-over frequency, i.e. are opened and closed again, that the switch-over frequency corresponds to the desired motor operating frequency. By virtue of the damping of the oscillatory circuit, a phase current of constant maximum amplitude is established which, with a low relative damping of the oscillatory circuit (it is of advantage if the $\cos \phi$ factor of the motor is poor), has a very good sinusoidal form which means that it is low in harmonics and has the desired operating frequency of the motor.

In principle, the arrangement shown in Figure 2 corresponds entirely so that in Figure 1, with the sole difference that instead of the mechanical switches $S1$ and $S2$ in the control unit E , electronic switches $S1$ and $S2$ are illustrated. The mode of action of such switches is well known and therefore requires no detailed description. They are switched in conventional manner by control voltage of appropriate switch-over frequency. Advantageously the switching paths of the switches $S1$ and $S2$ are bridged by free-run diodes $D1$, $D2$.

Figure 3 shows an embodiment of the drive unit of the invention, and is a three-phase arrangement. Once again, the unit is fed with a DC voltage U . Each of the three phases R , S and T is constructed as a series oscillatory circuit with C , L and W . In addition, a control unit E_R , E_S , E_T is associated with each phase. The switches $S1$ and $S2$ are appropriately identified by an

additional letter to characterise the phases, i.e. Sl_R , Sl_S and Sl_T and so on. These switches are illustrated here in the inoperative position. During operation, control is carried out in that, exactly as was mentioned above, one switch is always closed in each control unit E_R , E_S or E_T , while the other is open. In the three-phase representation, however, it must be remembered that actuation of the control units or of the switches contained therein occurs with a phase displacement of 120° . It is however possible also to construct a two-phase motor winding and to operate the control unit with a phase displacement of 180° .

Figure 4 corresponds in construction to the embodiment shown in Figure 3 and shows a three-phase drive unit with the phases R, S and T. The associated control units E_R , E_S and E_T are indicated by the broken lines and within these control units there are electronic switches Sl_R , Sl_S , etc., likewise each indicated in an area shown by broken lines. Also in the case of the embodiments in Figures 3 and 4, the mechanical or electronic switches are positively controlled from outside and no further description will be given here.

Figure 5 shows the associated operation of a group of drive units $M_1, M_2 \dots M_n$. Each of these drive units contains the three phases R, S and T with the inductance L and effective resistance W. Associated with each drive unit is its own control unit $G_1, G_2 \dots G_n$. These control units are shown by broken lines. The control units themselves once again contain for each phase a control unit E_R, E_S, E_T with switches Sl_R, Sl_S , etc. Once again, as above, a capacitor C is associated with each of these control units and, together with the motor winding, forms the aforesaid series oscillatory circuit.

Figure 6 again shows the associated operation of a group of drive units M_1 to M_n , these units are also connected in parallel, the mutually corresponding phases R, S and T being connected to one another. In contrast to Figure 5, however, a common control unit G is associated with the complete group of drive units. The control unit is indicated as an area bounded by broken lines. Once again in broken lines, it contains the control units E_R, E_S and E_T for each phase. The capacitors C_R, C_S and C_T are each associated with one phase and, together with the parallel connected motor windings or their inductances L and effective resistances W, form the necessary series oscillatory circuit.

Not only parallel connection but also series connection and combined series/parallel connection of drive units is possible. Figure 7 diagrammatically shows

the construction of a series-parallel connection.

The above description relates to normal operation at the desired operating frequency. However, running of the drive units up to speed is not possible at the desired operating frequency, and for this purpose, the drive units can be run up to speed by means of auxiliary devices until they are brought to the necessary speed, when the drive units are switched over to the above-described control network. Another possibility is to construct the control network and to arrange the capacitance of the oscillatory circuit, such that they are adapted to lower frequencies. By continuous raising of the switching frequency of the control network, the drive units can be run up to speed. The capacitance of the series oscillatory circuits must be modified accordingly.

WHAT WE CLAIM IS:—

1. Electronic drive unit for a high-speed appliance, the unit having a rotary electrical field acting on a rotor part wherein each phase of a drive winding, by incorporation of a capacitance, is constructed as a series oscillatory circuit tuned to an operating frequency, and wherein a remotely-actuated control unit alternately applies a direct current voltage to the oscillatory circuit or short-circuits the oscillatory circuit at a switch-over frequency corresponding to the operating frequency.

2. Electric drive unit according to claim 1, wherein the control unit has electronically operated switches.

3. Electric drive unit according to claim 2 having free run diodes bridging the switching paths.

4. A group of electric drive units according to any preceding claim, wherein each drive unit has a remotely operated control unit with control units for each motor phase.

5. A group of electric drive units according to any of claims 1 to 3 wherein the mutually corresponding phases of all the units are connected to one another and are in each case connected to a control unit of one of the remotely operated control appliances common to the group.

6. A group according to claim 5, wherein a common capacitance is associated with each phase for a group of units.

7. A unit or a group of units according to any of claims 1 to 6, wherein the capacitance of the oscillatory circuit is in each case grouped together with the control unit.

8. Electric drive unit for a high-speed appliance substantially as herein described,

with reference to Figures 3 to 7 of the accompanying drawings.

- 5 9. A group of electric drive units for high-speed appliances, substantially as herein described, with reference to Figures 5 to 7 of the accompanying drawings.

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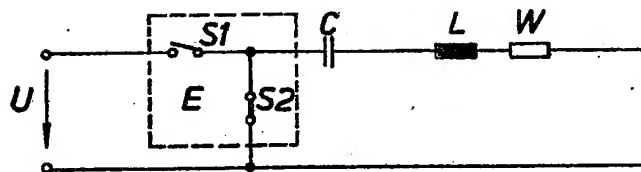


Fig.1.

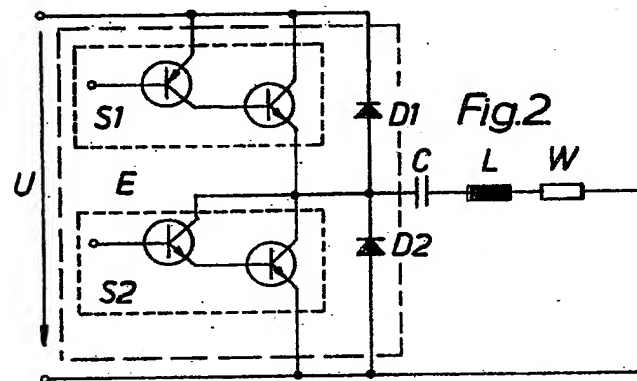


Fig.2

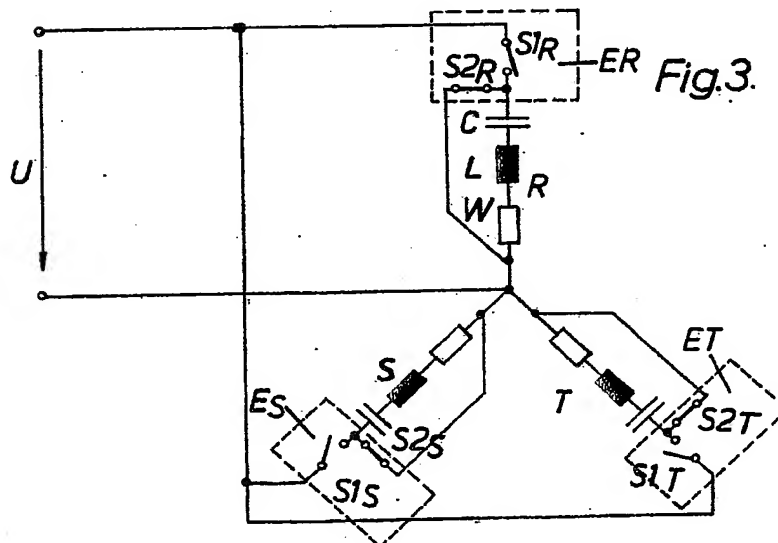
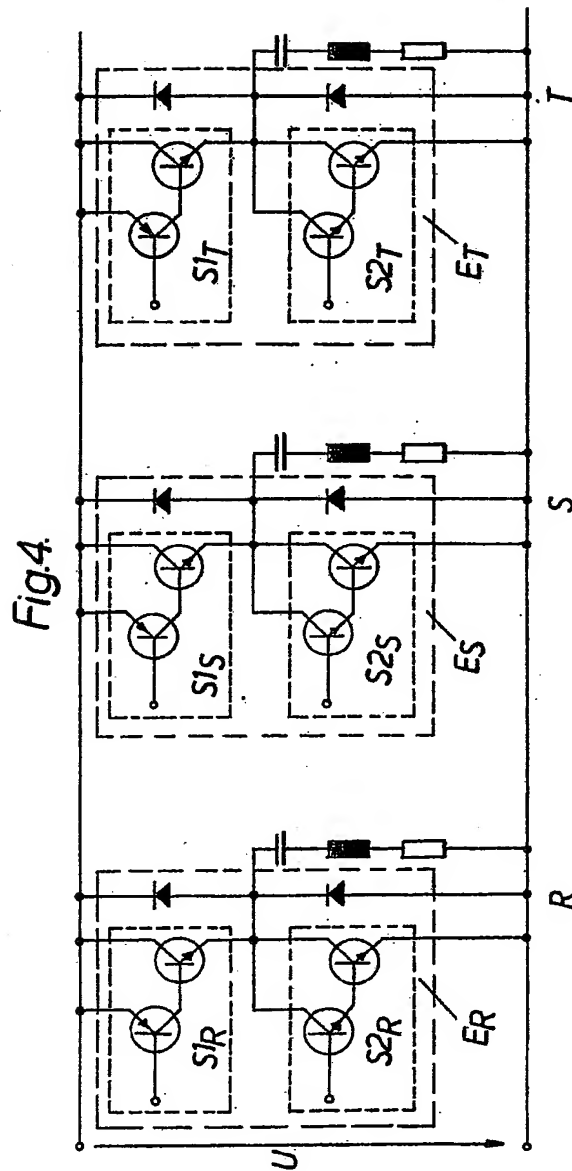


Fig.3.



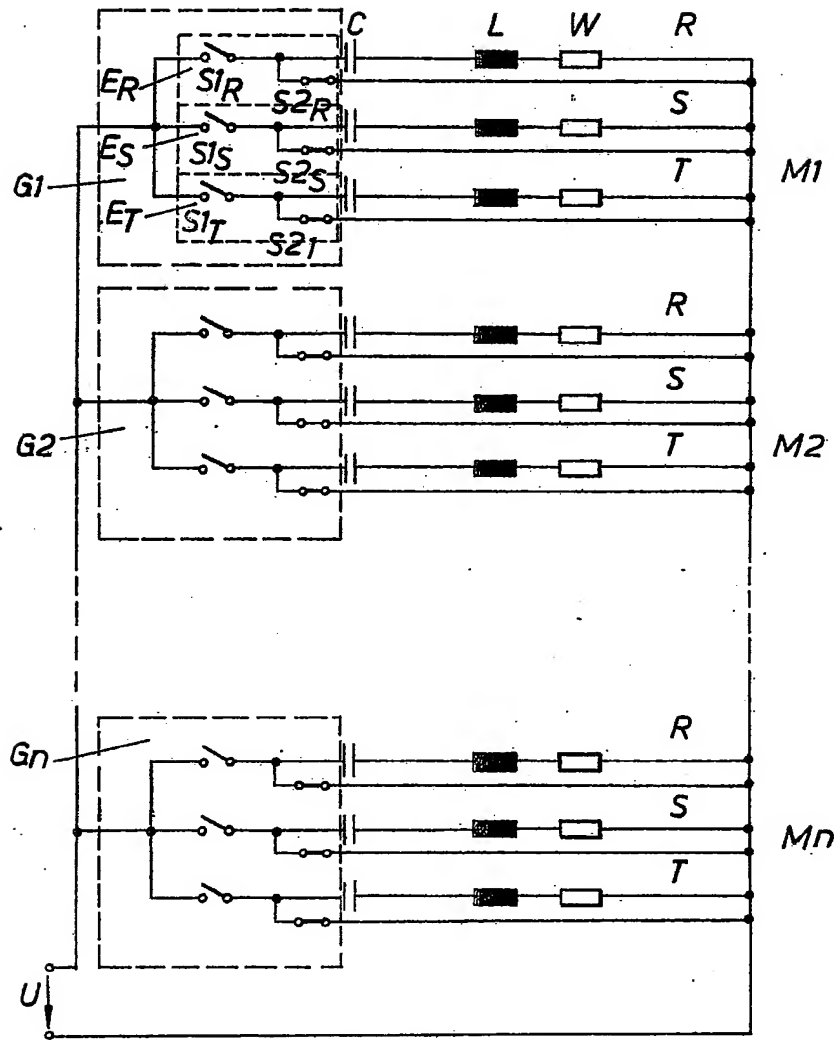


Fig.5.

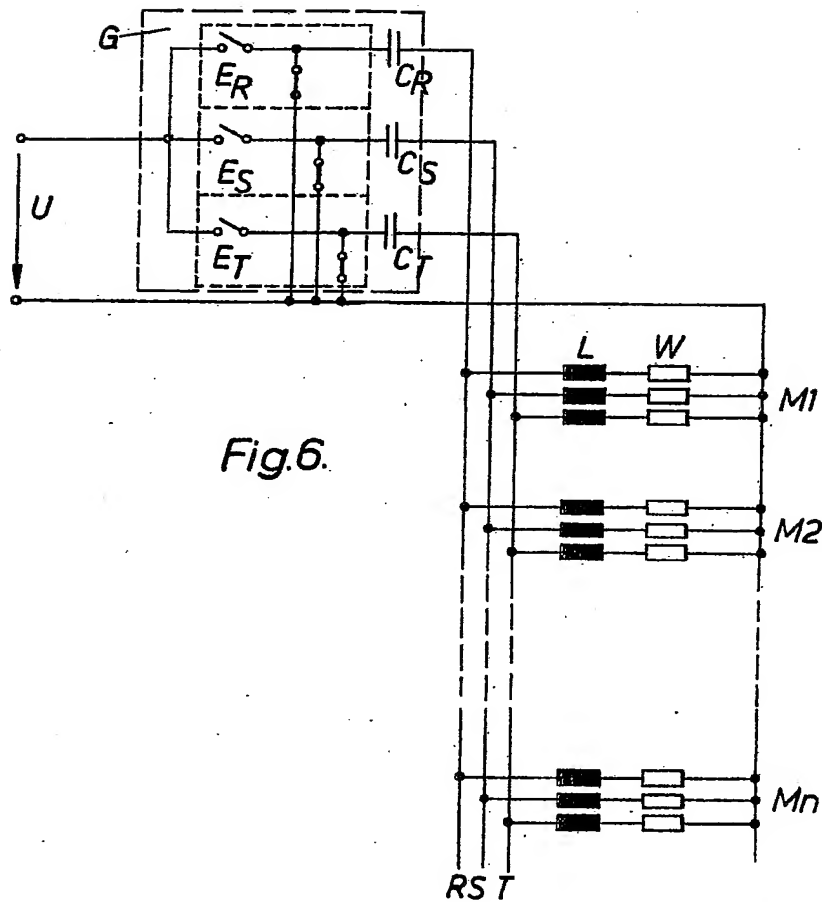


Fig. 6.

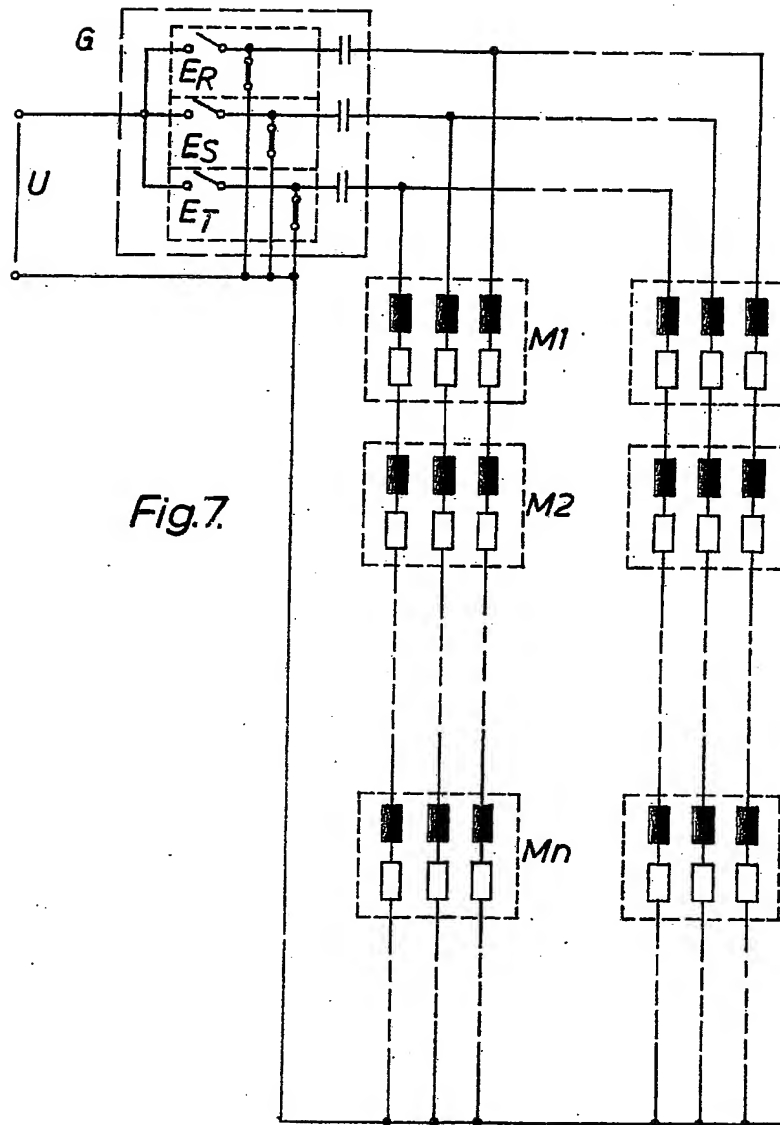


Fig.7.